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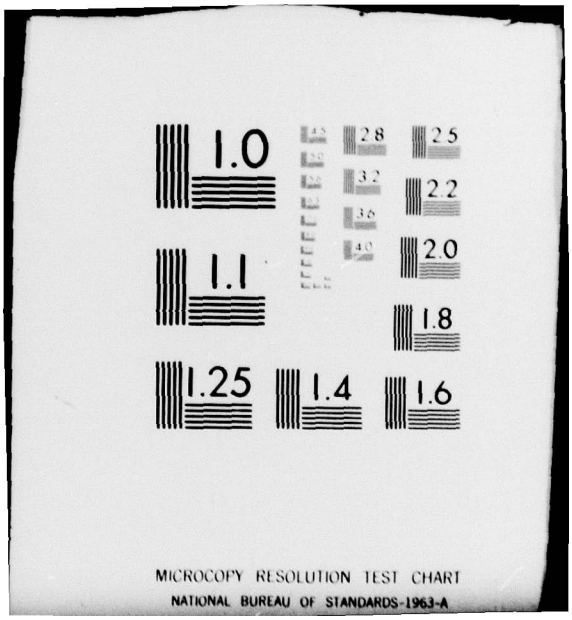
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During the past year of this grant substantial progress was made in two major areas of research. The first, which was the original focus of the grant in earlier years, is that of positive dynamic systems. This work has reached the point where it is useful for certain design problems. The second area of research, which has been a new focus for the past two years, is that of descriptor variable systems. Our efforts continue on the basic theory and application for the nonlinear case.

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Interim Report

for Grant on

DYNAMIC SYSTEMS

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

Grant No. 77-3141

December 1979

I. Introduction

During the past year of this grant substantial progress was made in two major areas of research. The first, which was the original focus of the grant in earlier years, is that of positive dynamic systems. This work has reached the point where it is useful for certain design problems. The second area of research, which has been a new focus for the past two years, is that of descriptor variable systems. Our efforts continue on the basic theory and application for the nonlinear case.

II. Postive Systems

(1) Structural Design for Positive Systems

Based on results developed in earlier years, on the output aggregation of positive linear dynamic systems, a new approach to the structural design for a class of positive dynamic systems was developed this year. The positiveness of the dynamic system, in particular the Frobenius-Perron properties, are exploited to convert the problem of designing the structure of a dynamic system into a constrained static optimization problem which can be solved by standard methods. (See enclosed publication list.)

(2) Reachable Set Description of Positive System

Let w_k be the set of all states at time k which can be reached by applying a positive control sequence $\{u(i)\}_{i=0}^{k-1}$. It is easily seen that w_k is a positive cone. A bound b_k for the reachable cone was developed and a dynamic description of the bounding cones $\{b_k\}$ was obtained that is similar to the

dynamic property of $\{w_k\}$ itself. With these bounds one can address the following questions. Assuming that the initial state is within certain cones, is it possible that one can transfer the state to a certain target cone? What is the maximal and minimal feasible time for such transfer? It is expected that these answers would lead to another new approach to structural design problems where the main concern is reachability of certain target cone within certain time period. (Publications based on these results are under preparation.)

III. Descriptor Variable Theory

A descriptor variable system is a system of dynamic equations which contains implicit, as well as the usual explicit, dynamic equations. The general form for such a system is:

$$g(x(k+1), x(k), u(k), k) = 0$$

$k = 0,1,2,\ldots,N-1$ where $x(k)$ is an n-dimensional "descriptor vector". Of course such a structure includes as special cases both purely static equations and purely dynamic (state space) equations. It also includes predictive (i.e. noncausal) systems.

Our research has continued to be focused in two major directions. The first is the exploration of various systems and problems that can be cast in this unifying framework. We have shown that various large-scale systems have natural representations in this form, and we have found many situations where the noncausal component is especially useful. In addition, we have found that many standard problems in system

theory (including optimal control problems, equilibrium problems, and simulation problems) have their most natural expression in descriptor variable form. Thus, this aspect of our research has gathered together, within a standard framework, a very large portion of existing system theory problems.

The second main direction of our research on descriptor variable systems is the development of algorithms for manipulating these systems. These include methods for transforming such systems to various canonical forms as well as methods for simply solving such systems. Of course, research on development of methods also requires that some research be devoted to the study of the structural characteristics of such systems, and several structural insights have been discovered. However, this study is always motivated primarily by the desire to develop procedures for solving classes of problems.

During the past year our work has focused heavily on the formulation and solution of dynamic equilibrium problems using the descriptor variable framework. Such problems are similar to optimal control problems, but are more complex, since they may involve the simultaneous solution of several optimal control problems. Such problems arise in economic systems and in systems with decentralized control or command. It is expected that a great deal more effort will be devoted to this area in the next year.

Publications Resulting from Grant

[1]. Luenberger, David G. "Non-Linear Descriptor Systems", Journal of Economic Dynamics and Control 1 (1979) 219-242.

[2]. Rouhani, Ramine, "Aggregation of Positive Linear Systems", Ph.D. Dissertation, Stanford University, August, 1978.

[3]. Rouhani, R. and E. Tse, "Bounding the Behavior of Positive Dynamic Systems", to appear in Journal of Economic Dynamics and Control.

[4] Rouhani, R. and E. Tse, "Structural Design for Classes of Positive Linear Systems", submitted to IEEE Trans. on Systems, Man & Cybernetics.